Evaluation of Forecasts of the Water Vapor Signature of Atmospheric Rivers in Operational Numerical Weather Prediction Models

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Motivation

Why atmospheric rivers?

Atmospheric rivers (ARs) are constantly moving, narrow filamentary bands of intense water vapor transport through the lower atmosphere. Recent studies (e.g., Ralph et al., 2006) demonstrated that these ARs were present and were an important contributor to recent extreme precipitation and major flooding events along the west coast. The events also contribute up to 50% of the seasonal water supply in the Sierra Nevada mountains.

The problem

Given the impact of these events, it is critical to understand how well they are forecast. This study is an initial attempt to quantify the ability of several leading numerical weather prediction (NWP) models to reproduce the frequency, width, and intensity of atmospheric river events.

Key Questions

Are ARs reproduced with the proper frequency in reanalyses and forecasts?
Are the widths of the atmospheric rivers reproduced accurately?
Are there any biases in the modeled strength of the atmospheric rivers?
Are these results a function of model resolution and forecast lead time?

Approach

The ability of several NWP models to reproduce ARs is evaluated through comparison of their integrated water vapor (IWV) fields with satellite observations. The technique makes use of the objective, automated atmospheric river detection tool (ARDT) developed and validated by Wick et al. (2013). All models were drawn from the THORPEX Interactive Grand Global Ensemble (TIGGE).

Satellite Observations

Integrated water vapor retrievals from passive microwave brightness temperatures from the SSM/I and SSMIS

- Wentz optimal statistical algorithm
- 12-hourly composites from multiple satellites centered on forecast time

NWP Models Evaluated

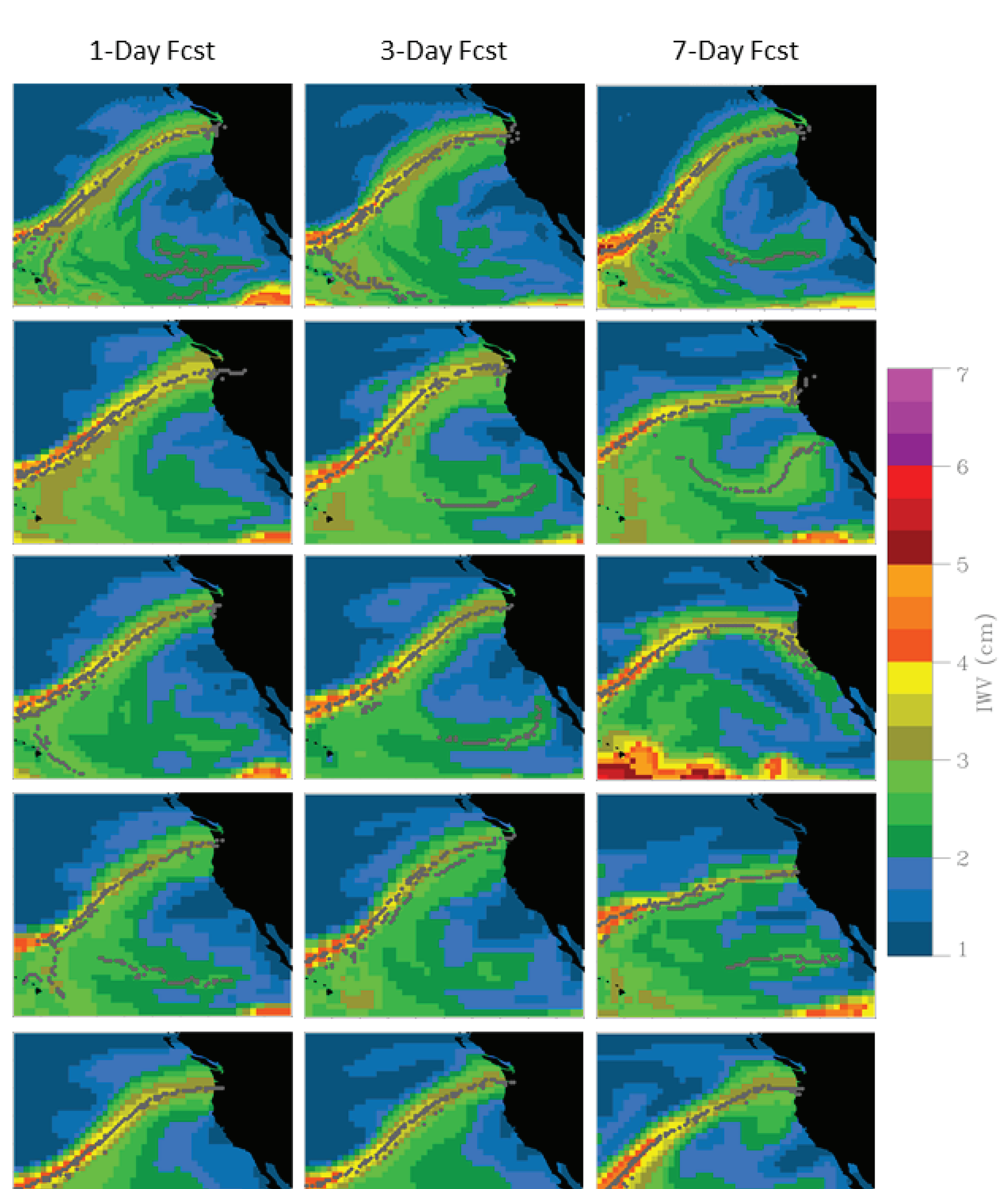
Control forecasts of total column water; 12 UTC Initialization

- ECMWF
- UKMO - UK Met Office
- NCEP
- JMA - Japanese Meteorological Agency
- CMC - Canadian Meteorological Centre

Forecast lead times analyzed: 0, 3, 5, 7, and 10 days

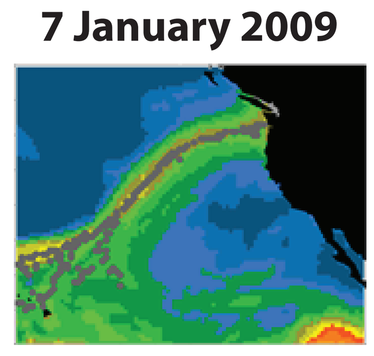
Analysis period: 3 cool seasons (Oct - Mar) from 2008-2009 to 2010-2011

Illustration of Technique



The verification technique is illustrated for an AR on 7 January 2009. The panels to the left show the forecasts from the different models out to 7 days. The axis of the AR detected by the technique is shown with the overplotted circles. The panel below shows the AR as observed by SSM/I.

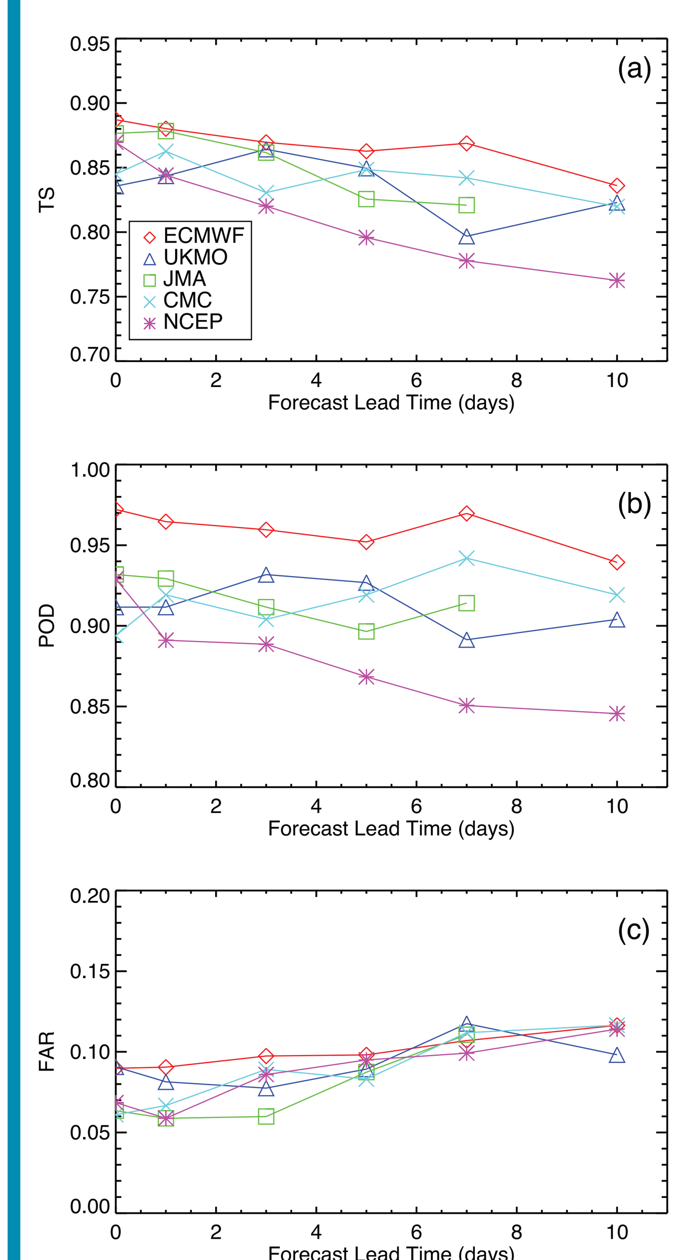
Satellite Observations 7 January 2009



All models forecast the occurrence of the AR with 7-10 day lead time, but the position, width, orientation, and strength vary significantly with model lead time and resolution. The location of landfall, in particular, is highly variable.

Representation of Frequency of Occurrence

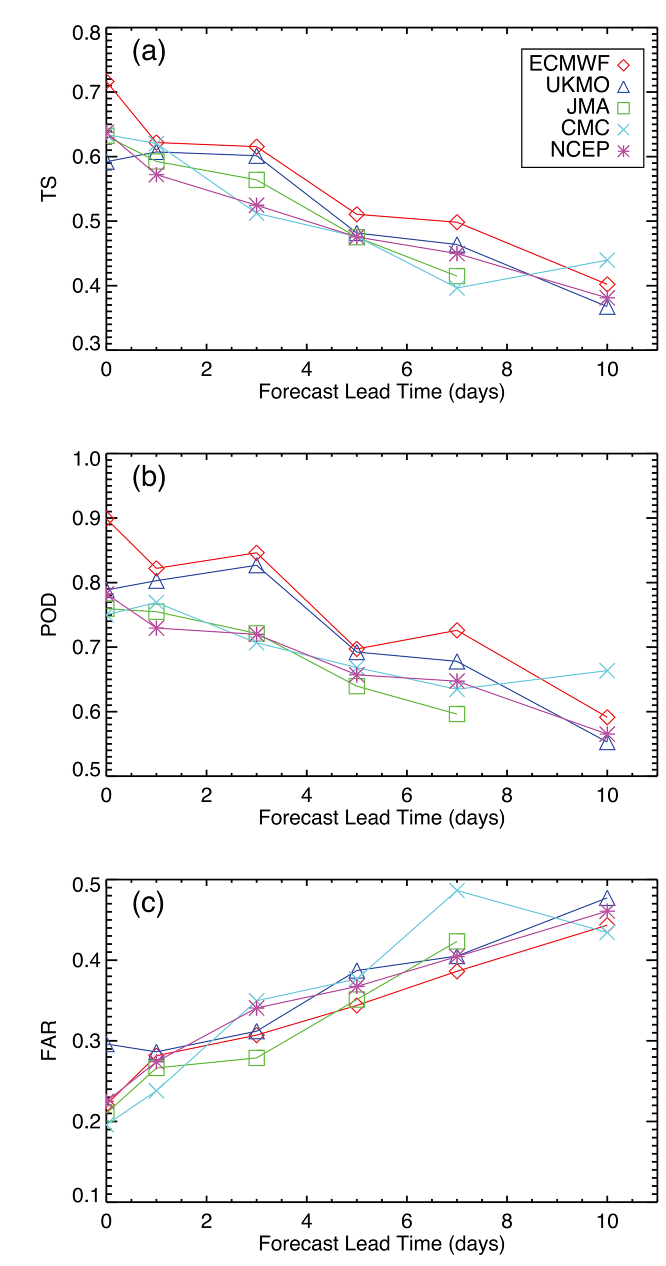
All Events



The overall occurrence of ARs is well forecast, even out to 10-day lead times. The probability of detection is >84% and the false alarm rate is <12% for all models at all lead times.

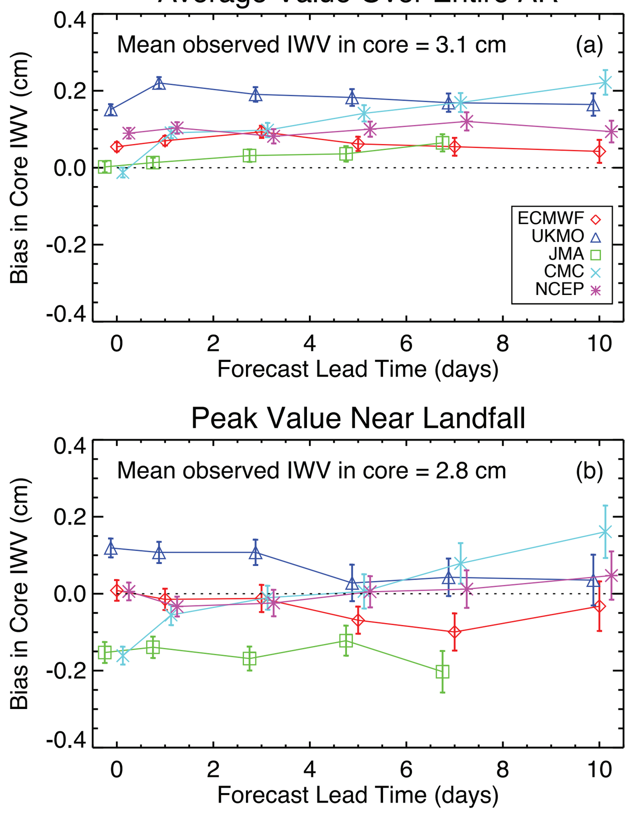
The forecasting of landfalling events is poorer and the skill degrades with lead time. Threat scores are decreased (relative to that for overall AR occurrence by values ranging from 0.25 at 1-day lead time to over 0.4 at 10-day lead. The relative performance of the models remains generally similar.

Landfalling Events



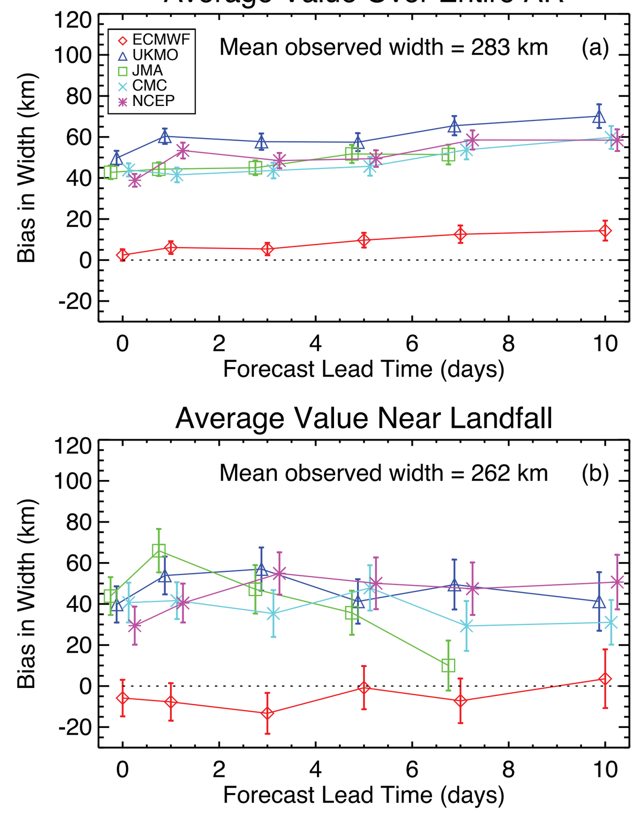
Errors in Width, IWV Content, and Landfall Position

Core IWV Content



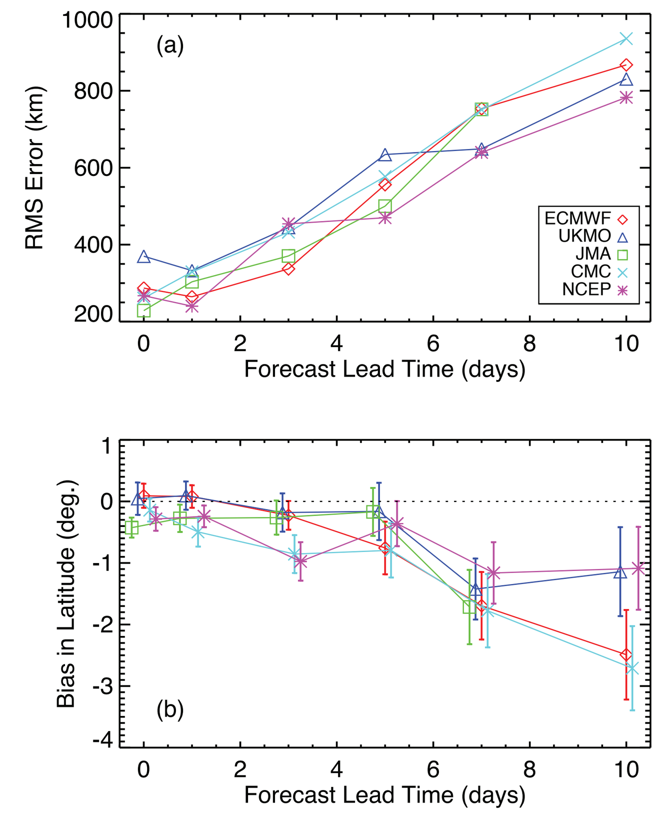
The IWV content along the AR axis was compared both along the entire AR length and near landfall. A slight moist bias is observed in all models overall while little bias is observed near landfall. The biases are largely independent of forecast lead time.

Width



Width comparisons demonstrate the superior performance of the ECMWF model and a significant overestimate of width by all other models. The biases reflect the impact of model resolution with the 1-deg models spreading the AR signature over a greater width than the 0.5-deg ECMWF.

Position at Landfall



The rms error in landfall position increases significantly with forecast lead growing from values near 200 km to more than 800 km at 10-day lead. The errors in position generally correspond to a southerly bias in landfall location. The rms errors generally exceed hurricane track forecast errors.

Conclusions

- The ability of 5 operational NWP models to accurately predict and reproduce the IWV signature of ARs was evaluated using the automated ARDT.
- The overall frequency of occurrence of ARs is well forecast, even out to 10-day lead.
- Forecasts of landfall occurrence are poorer and degrade with increasing lead time.
- Errors in landfall position are significant, increasing to over 800 km at 10-day lead time.
- Model resolution is important for accurate representation of detailed characteristics, but realistic ARs were still predicted by coarser resolution models.
- Model performance was generally similarly, though ECMWF provided better width estimates due to its 0.5 deg. spatial resolution.

References

Ralph, F. M., P. J. Neiman, G. A. Wick, S. I. Gutman, M. D. Dettinger, D. R. Cayan, and A. B. White, 2006: Flooding on California's Russian River: Role of atmospheric rivers. *Geophys Res. Lett.*, **33**, L13801, doi:10.1029/2006GL026689.

Wick, G. A., P. J. Neiman, and F. M. Ralph, 2013: Description and validation of an objective automated technique for identification and characterization of the integrated water vapor signature of ARs. *IEEE Trans. Geosci. Rem. Sens.*, *in press* (*available online*).